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Wavelet Based Assessment of Crop Yield Risk in Multiple Crop Insurance

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Abstract

Crop insurance plays an important role in the stability and growth of the agriculture sector. Researching methods, including the wavelet methodology, Nonparametric (kernel) Density Estimation and VaR were discussed. Then we show the measurement procedure of measuring the yield risk of crops, including crop yield sequence processing and statistical features analysis; assessing the distribution of crop yield risk and calculation of crop yield risk value. The empirical results show that the degree of risk from low to high were rice, maize, wheat, cotton, soybean, oilseeds and peanut. Results show that this insurance type has seldom been met in Jiangsu and is unattractive to farmers. The government should carry out more insurance type, such as peanut, oilseeds, which may suffer more risk to meet the need for farmer.

Key words: Crop insurance; Wavelet methodology; Kernel density estimation

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INTRODUCTION

Crop insurance plays an important role in the stability and growth of the agriculture sector, constructing a more stable grain supply for people. Crop insurance as a risk management tool has grown rapidly in recent years.

In China, agricultural insurance has developed further since its occurrence in 1950s. In 2001, the crop insurance premium income was only 300 million CNY. Since 2007, China government began the premium subsidy and the insurance premium had made great breakthrough. The amount of premium was 13.9 billion CNY in 2010, and the number had reached 56.6 billion CNY in 2013. In November 12, 2012, agricultural insurance regulations were formally implemented. Generally speaking, the trend of crop insurance in China is developing fast.

The type of crop insurance product is an important part in crop insurance, and has directly impact on farmer' demand for agricultural insurance. In USA, two mainly insurance products are yield insurance products and income insurance products. Yield insurance products include MPCI and GRP. MPCI insurance will make sense when the crop is damaged by drought, floods, volcanic eruptions, etc. Currently, the major insurance products in China are also MPCI which coverage is against actual yield below the predetermined guaranteed yield.

Major insurance commodities, including corn, oilseed, etc., are presented in Jiang Su, Shan Dong, He Nan and Si Chuan Provinces. In Jiang Su province, Rice and Wheat can be insured additionally in crop insurance product.

We carried out our research on agricultural insurance in Jiangsu Province because Jiangsu Province was listed as one of the six agricultural insurance experimental provinces by the Ministry of Agriculture, the Ministry of Finance, the Insurance Regulatory Commission in 2007. Agricultural insurance in Jiangsu has already formed Huai-An, Su-zhou and Wu-xi patterns.

Different varieties in plantation may face different degree of risk. From the perspective of the insurance needs in farming, farmers hope that the insurance company is able to provide a higher degree of risk varieties. In fact, the objects that can be insured are limited, only rice, wheat, corn, oilseed, etc. in crop industry and pigs, cows in breeding industry can be insured. However, the above objects included may face the least risk.

This paper is organized as follows: Section 2 discusses researching method, including the wavelet methodology, Nonparametric (kernel) Density Estimation and VaR. Section 3 shows the measurement procedure of measuring the yield risk of crops. The data information and the empirical results are presented in Section4. Section 5 provides some conclusions of the study.

1. METHODOLOGY

1.1 Wavelet Analysis

The wavelet transform employs a compact portion of a wavelet as a base function. Thus, it is a time and frequency analysis and it can determine the signal using time and frequency, see Chui (1992), Daubechies (1992), Hernadez (1996), Mallat (1989).

The series were transformed using wavelet transform, a relatively new mathematical tool in finance field. A given data according to scale instead of frequencies can be decomposed as in the Fourier approach. Wavelet analysis, in contrast to Fourier analysis, does not need any stationary assumption in order to decompose the series as spectral decomposition methods perform a global analysis, whereas the wavelets method acts locally in time.

For any suitable choice of function $\phi(.)$, we can define the two wavelets, naming father and mother wavelets:

$$\phi_{J,K} = 2^{-\frac{J}{2}}\phi\left(\frac{t-2^J K}{2^J}\right) \qquad \int \phi(t)dt = 1 \tag{1}$$

And

$$\psi_{j,k} = 2^{-\frac{j}{2}}\psi\left(\frac{t-2^j k}{2^j}\right), j=1,\cdots J \qquad \int \psi(t)dt = 0 \tag{2}$$

$\psi_{j,k}$ and $\phi_{J,K}$ are two basis wavelet filter functions, naming father wavelet and mother wavelet. The wavelet transform maps a function $f(t)$ from its original representation in the time domain into an alternative representation in the time-scale domain by recursively applying two. The mother wavelet must satisfy an admissibility criterion in order to get a stably invertible transform.

For facilitating the mathematical development and analysis, the above statements must meet the need that the scale parameter "s" equals to the dyadic scale 2^j.

Given this family of two basis functions, we can define a sequence of coefficients that represent the projections of the observed function onto the proposed basis.

$$s_{J,K} = \int f(t)\phi_{J,K}\mathrm{d}t \qquad d_{j,k} = \int f(t)\psi_{j,k}\mathrm{d}t \tag{3}$$

Given the coefficients the function, $f(t)$ can be represented by:

$$f(t) = S_J + D_J + D_{J-1} + \cdots D_1 \tag{4}$$

where

$$S_J = \sum_k s_{J,K}\phi_{J,K}(t) \qquad D_j = \sum_k d_{j,k}\psi_{j,k}(t) \qquad j=1,\cdots J \tag{5}$$

The easiest way to visualize the above is to consider a sequence of topographical maps; S_J provides a smooth outline and each D_j in turn provides a higher level of detail.

Equation 5 indicates that the complete function will be obtained by the multi-resolution of the signal, but less detailed can be obtained as:

$$S_j = S_J + D_J + \cdots + D_{j+1} \tag{6}$$

1.2 Nonparametric (Kernel) Density Estimation

A disadvantage of the parametric method is that it needs the real parameters of density function, such as t-distribution, normal- distribution. In nonparametric approach, f(*x*) estimates will not assume the form directly.

We seek the probability density function (pdf), f(*y*), of a random variable *Y*, We call this estimate $\hat{f}(y)$. The use of nonparametric density estimation has been used for many years and in many field applications, such as economics, education, etc. It can be computed by the data histogram. However, although histograms are useful for graphical depiction of complicated data, they may have two important drawbacks: discontinuity and the fact that the choice of origin changes the estimate.

To settle these problems, we recur to the definition of pdf and we have kernel density estimator *K*(.) with the following characteristics:

(1) $K(.)$ continuous; (2) $K(z) \geq 0$ for all z; (3) $\int K(z)\mathrm{d}z = 1$

Once this function is found, $\hat{f}(y)$ can be expressed as:

$$\hat{f}(y) = \frac{1}{h}\sum_{i=1}^{n} K\left(\frac{Y_i - y}{h}\right) \tag{7}$$

From the conditions above, it is clear that $\hat{f}(y)$ will be a pdf (*b, c*) and that it will be continuous.

To use the kernel estimator, the size of the bandwidth *(h)* and the kernel function must be considered. It has been determined by several authors (Hardle, 1990; Silverman, 1986; Jae-Lee, 1996; Fox, 1990; Rao, 1991) that the latter choice is not as important as the former. The bandwidth determines the degree of smoothing of the estimated density, and is equivalent to the number of bins employed to compute histograms. Regarding the choice of indicator function, Epanechinikov kernel was often used.

1.3 Value at Risk

With the development of rapid globalization, firms gradually recognize the growing importance of risk management. This increased focus on risk management has led to the development of various methods and tools to measure the risks firms face.

VaR is becoming one of the most important methods to measure the risk of an asset or portfolio since its inception in the early 1990s. More and more financial regulations and institutions use it to measure and manage risk, such as the group of 10 banks, the group of 30 banks, the Bank for International Settlements, European Union and Basel Committee.

The attraction of VaR is its simplicity. VaR is the value that equals maximum expected loss over a given horizon period at a given level of confidence. The $\mathrm{VaR}(\alpha)$ of return can be defined by the equation

$$p(r \le \mathrm{VaR}(\alpha)) = \alpha \ .$$

α, the significance level, is usually a small percentage. When other conditions keep constant, if α becomes smaller, then the absolute value of $\mathrm{VaR}(\alpha)$ becomes larger. According to the equation, $\mathrm{VaR}(\alpha)$ depends mainly on the significance level, the time interval and the distribution of portfolio return. Different significance levels and models mar lead to different VaR values.

Traditionally, there are three methods naming variance-covariance method, historical method and Monte-Carlo simulation, applied to estimated VaR. The value of VaR is closely related to the tail of the distribution. In our study, we do nonparametric estimation to construct the distribution of portfolio return which does not depend on the assumption of return distributions.

2. THE MEASUREMENT PROCEDURE OF MEASURING THE YIELD RISK OF CROPS

Crop yield risk value refers to the degree of the risk of the crop production in a certain period of time under normal market conditions and a certain confidence level. Under this definition, the measurement of the risk value of the crop yield risk in China should abide by the procedures indicated below.

(1) Crop yield sequence basis analysis. Research of crop yield risk should remove the trend of history data first by wavelet method, and study the data bias which can be derived from the following equation

$$bias = \frac{y - y_t}{y}$$

Where y and y_t refer the actual yield and the trend yield of crop per acre.

(2) Estimation of the distribution of crop yield risk using nonparametric density.

Despite the variance as well as other simple statistics of crop yield volatility can roughly describe its risk situation; however, these simple statistics imply the assumption that different volatilities of crop yields have the same probability. Variance describing how far the returns lie from the mean cannot conclude any change in the market risk. Therefore, it is necessary to construct the probability distribution model considered suitable to the crop yield risk, thereby ensuring accuracy in the measurement of crop yield risk.

(3) Calculation of crop yield risk value. An optimal probability distribution model suitable to crop yield risk was used to calculate the lower quartiles under a certain confidence level using nonparametric density estimation.

3. EMPIRICAL ANALYSIS

We collect the annual crop yields from www.zzys.moa.gov.cn. The period covers the time from 1978 to 2011. The crops are consisted of seven varieties, including corn, wheat, peanut, rice, soybean, oilseeds. These crops plantation area is more than 75% proportion in the whole plant area in Jiangsu Province.

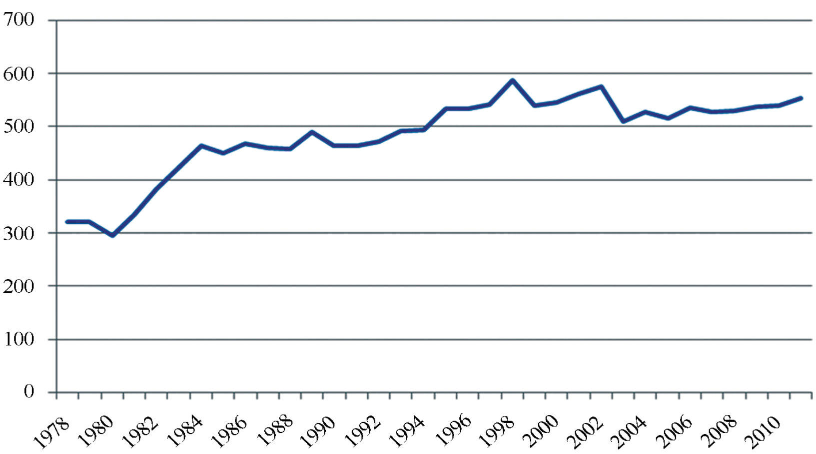

Figure 1
The Actual Rice Yield Annually from 1978 to 2011

The trend rice yield can be calculated by the wavelet method. See Figure 2.

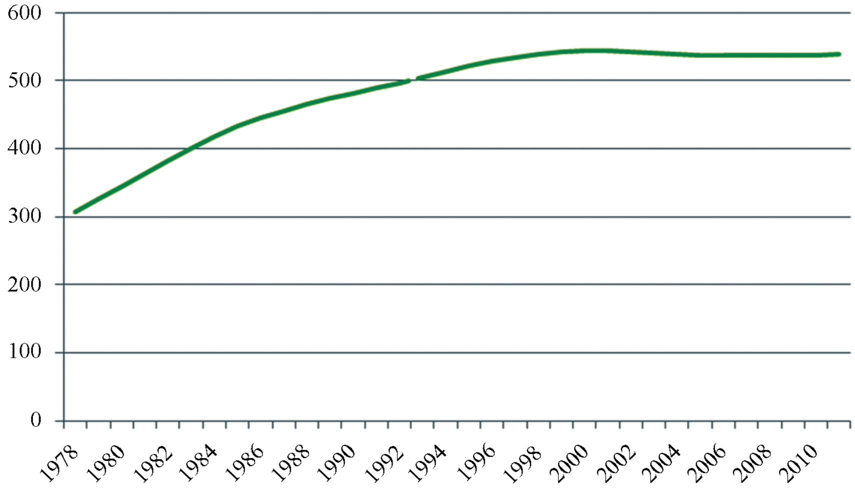

Figure 2
The Trend Rice Yield

Then we study the data bias. See Figure 3.

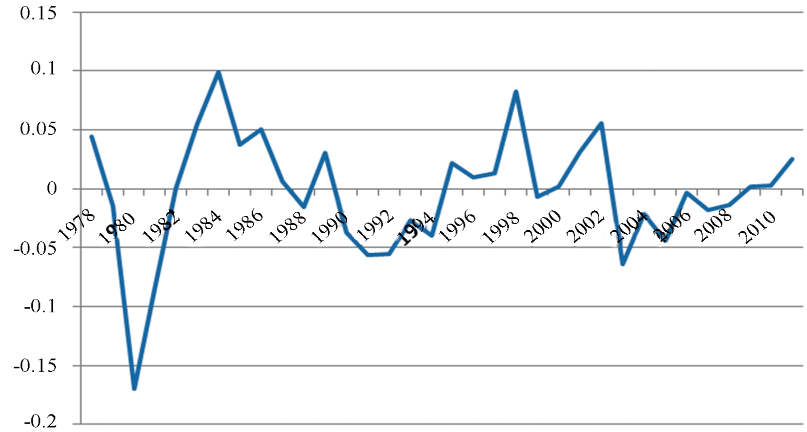

Figure 3

The Data Bias

The distribution of crop yield risk using nonparametric (kernel) density estimation is assessing. See Figure 4.

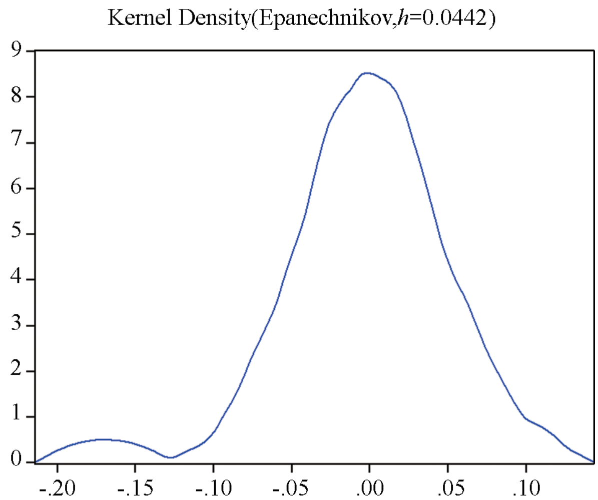

Figure 4
Nonparametric (Kernel) Density Estimation Is Assessing

The lower quartiles under 95% confidence are calculated.

The empirical results show that the degree of risk from low to high were rice ,maize, wheat, cotton , soybean, oilseeds and peanut.

CONCLUSION

The type of crop insurance product is an important part in crop insurance. In China, the crop insurance type is limited. The types of agricultural insurance in Jiangsu are mainly rice and wheat. However, the degree of risk of these two species is not high, which are listed in the last and the last but two of all species. Results showed that this insurance type has seldom been met in Jiangsu and is unattractive to farmers. The government should carry out more insurance type, such as peanut, oilseeds, etc, which may suffer more risk to meet the need for farmer.

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